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(54) Title: SYSTEM AND METHOD FOR STRESS AND PRESSURE SENSING IN AN IN-VIVO DEVICE

(57) Abstract: An in-vivo sensing device typically associated with an in-vivo imaging device may be adapted to measure endoluminal pressure or stress. The sensing device may include a substantially transparent base, a pressure-sensitive membrane, and fluid between the transparent base and the membrane. Incident light may be radiated through the substantially transparent base and the fluid of the in-vivo pressure-sensing device. This light may be reflected to a light detector, enabling measurement of in-vivo pressure on the membrane.

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SYSTEM AND METHOD FOR STRESS AND PRESSURE SENSING IN AN IN-VIVO DEVICE

FIELD OF THE INVENTION

[0001] The present invention relates to in-vivo sensing, and particularly to a system, device, and method to sense stress and/or pressure using an in-vivo imaging device.

BACKGROUND OF THE INVENTION

[0002] The gastrointestinal (GI) tract is a typically convoluted long tube that folds many times to fit inside the abdomen, proceeding through the esophagus, stomach, duodenum, and small intestine. The small intestine is connected to the large intestine. Matter, such as food, is passively moved through the GI tract and pushed through muscular valves due to muscular action of the GI tract wall, namely, peristalsis. Motility in the GI tract is achieved via pressure exerted by the GI tract walls.

[0003] Ingestible in-vivo devices, such as electronic capsules, which are moved through the digestive tract through the action of peristalsis and which may collect data and transmit the data to a receiver system are known. These devices may include, for example, an imaging system for obtaining images from inside a body lumen, which may be transmitted to an external receiving unit.

[0004] Systems for measuring pressure, for example endoluminal pressure, are known. For example, gastric pressure may be measured by pressure sensors carried on the end of endoscopes or catheters. However, these methods may cause patient discomfort and may not be able to sense the entire GI tract. Gastric pressure has been known to be measured and the measured information transmitted from the body by an autonomous ingestible device consisting, for example, of a diaphragm assembly, which may be

inserted into the GI tract such that any movement of the gastrointestinal environment (typically containing fluids) may be sensed as pressure. These measurements may be useful for indicating a pressure that is exerted uniformly throughout the lumen. However, stress or local pressure of the GI tract walls may not be easily measured.

[0005] It may be useful to know if and when stress or local pressure is exerted by a body lumen wall, for example, in order to get an indication of the peristaltic forces that may reflect on the general state of the GI tract, and specifically on the nerve-muscle status of a specific section of the GI tract.

SUMMARY OF THE INVENTION

[0006] According to an embodiment of the present invention, there is provided a system and method for sensing in-vivo stress and/or pressure using an in-vivo device such as, for example, an ingestible capsule with optical means. The system may include a stress-sensing device configured to convert endoluminal mechanical forces or pressure into optical signals that may indicate, for example, endoluminal stress or pressure.

[0007] According to some embodiments of the present invention, the in-vivo sensing device may include, for example, a substantially transparent base, a pressure-sensitive membrane, and a fluid disposed between the transparent base and the membrane. The in-vivo device may be associated with an imaging system, which may, for example, image light reflected off the membrane, to indicate changes in local stress or pressure on the in-vivo device.

[0008] According to some embodiments of the present invention, an in-vivo sensing method may be provided that includes, for example, radiating a beam through a substantially transparent base and a fluid of an in-vivo pressure sensing device, where the fluid is adjacent to a flexible membrane; recording the reflected light using a detector; and measuring in-vivo pressure on the membrane.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

[0010] Figure 1 is a schematic sectional view illustration of a sensor, constructed and operative in accordance with an embodiment of the present invention;

[0011] Figures 2A-2C illustrate, in enlarged detail, the sensing device of the sensor of Fig. 1;

[0012] Figure 3 is a schematic illustration of an exemplary ingestible capsule;

[0013] Figure 4 schematically illustrates a sensor incorporated within an ingestible capsule, constructed and operative in accordance with an embodiment of the present invention;

[0014] Figure 5 is a schematic illustration of an in vivo device and processing system in accordance with an embodiment of the present invention;

[0015] Figures 6A-6C illustrate, in enlarged detail, aspects of the construction and operation of the sensor of Fig. 4;

[0016] Figures 7A and 7B schematically illustrate a stress sensing system in accordance with a further embodiment of the present invention; and

[0017] Figure 8 schematically illustrates a method for in-vivo pressure measurement, according to some embodiments of the present invention.

[0018] It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements throughout the serial views.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The following description is presented to enable one of ordinary skill in the art to make and use the invention as provided in the context of a particular application and its requirements. Various modifications to the described embodiments will be apparent to those with skill in the art, and the general principles defined herein may be applied to other embodiments. Therefore, the present invention is not intended to be limited to the particular embodiments shown and described, but is to be accorded the widest scope consistent with the principles and novel features herein disclosed. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, and components have not been described in detail so as not to obscure the present invention.

[0020] An in-vivo device, according to some embodiments of the present invention, may be typically autonomous and typically self-contained. For example, the in-vivo device may be a capsule or other unit where all the components are substantially contained within a container or shell, and where the in-vivo device does not require any wires or cables to, for example, receive power or transmit information. The in-vivo device may communicate with an external receiving and display system to provide display of data, control, or other functions. For example, power may be provided by an internal battery or a wireless power receiving system. Other embodiments may have other configurations and capabilities. For example, components may be distributed over multiple sites or units. Control information may be received from an external source.

[0021] Some embodiments of the present invention provide an in-vivo stress or pressure-sensing device which may directly convert mechanical forces into optical signals. These optical signals may indicate endoluminal pressure or stress, which may relate, for example, to the force acting on a unit area. In an embodiment of the present invention, the pressure-sensing device may be

configured, for example, to operate with an in-vivo device, such as an ingestible capsule, which may contain the sensing device.

[0022] It will be appreciated by persons skilled in the art that though reference is herein made to an in-vivo imaging device, for example, the present application is not limited thereto but may also be applicable to other in-vivo devices that utilize optics, such as, for example, endoscopes. Furthermore, the device, which may be, for example, an ingestible capsule, may also contain other types of sensing devices, such as devices to measure pH, temperature, electrical impedance, and bio-signals etc.

[0023] Reference is now made to **Fig. 1**, which is a schematic sectional view illustration of a sensing module, generally designated 10, constructed and operative in accordance with an embodiment of the present invention. Sensing module 10 may include a rigid housing 12 enclosing a fluid reservoir 14. Housing 12 need not be rigid. Sensing module 10 may include a sensing device 16. Sensing device 16 may include a substantially transparent base 22 on the inner face of housing 12 and a stress or pressure-sensitive membrane 20 on the outer face of housing 12. Sensing device 16 may have stress or pressure-sensitive material, for example fluid 24, between inner face 22 and outer face 20. Openings 26 may be formed within transparent base 22 thereby allowing communication between contents in sensing device 16, for example fluid 24, and contents in a reservoir, such as fluid reservoir 14. Fluid 24 may be substantially transparent, to allow the passage of light or other electromagnetic radiation through fluid 24. In other embodiments fluid 24 may be non-transparent.

[0024] According to one embodiment of the present invention, the fluid layer transparency may be, for example, between 1 and 0.01, where transparency (Tr) is defined as the intensity of transmitted light (Lt) as a proportion of the intensity of incident light (Li), or Tr=Lt/Li. The fluid viscosity, at 37° C, for example, may be 0.5 – 1.0 CentiPoise (cp). Higher viscosities, e.g. 1 – 100 cp may slow the response time of sensor 16. Such higher viscosity material may be used, for example, in cases where a relatively slow response time is acceptable or required. Other transparencies and viscosities may be used. Fluid 24 may include, for example, a gaseous or liquid fluid, such as water

(possibly with suitable additives such as colorants), saline solution, glycerin, or other appropriate fluid.

[0025] It will be appreciated by persons skilled in the art that although fluid reservoir 14 is shown in Fig. 1 as a single entity, it may comprise two or more separate reservoirs in communication with fluid 24 within sensing device 16. Reservoir 14 may be configured to expand, for example to receive expelled fluid 24, optionally without changing the pressure on sensing device 16, by, for example, unfolding collapsed areas within reservoir outer walls 15. Other ways of expanding may be used.

[0026] Base 22, which may be rigid or substantially rigid, may be transparent or substantially transparent to enable penetration of incident light or other electromagnetic radiation reaching base 22 from a light source. Base 22 may be non-rigid. Base 22 may further enable penetration of reflected light that reaches base 22 through fluid 24, after being reflected off membrane 20. Base 22 may be non-transparent and may have alternative properties to enable light penetration. Base 22 may be constructed from any suitable transparent or partially transparent material, such as glass, polystyrene or Lucite® acrylic (e.g., as manufactured by Ineos Acrylics Inc. USA), for example. Base 22 may be located on or proximate to membrane 20, which may be proximate to the outer face of an in-vivo sensing (e.g., imaging) device shell.

[0027] Membrane 20 may be a flexible membrane, such as an elasticized membrane or any other flexible structure that may preserve the integrity of sensing module 10 and may be configured to enable pressure or stress measurement, for example, by stretching or bending within a pre-determined range of forces being measured. Membrane 20 may be substantially reflective to reflect incident light towards a light detector. Membrane 20 may be opaque. Membrane 20 may be constructed from, for example, any elastic material that may be formed into a relatively thin membrane. For example, non-transparent membranes constructed from metal such as, for example, steel, titanium, etc. may be used. Other transparent or non-transparent membranes may be made of plastics such as, for example, polysterene, polycarbonate, Teflon,

etc. Membranes constructed from other materials or elements, or combinations of other materials or elements may be used.

[0028] Reference is now made to Figs. 2A-2C, which are enlarged details of sensing module 10 illustrating its operation according to an embodiment of the invention. In the examples of Figs 2A-2C, two fluid reservoirs 14a and 14b are shown for illustrative purposes only. Any other appropriate number of reservoirs may be used.

[0029] As illustrated in **Fig. 2A**, incident light or electromagnetic radiation 30 from a light source (not shown) may pass through base 22 and fluid 24, and is reflected off membrane 20. The reflected light beams 32, which may be attenuated by the passage through fluid 24, may be measured by a light detector unit, such as a photosensitive unit or photocell (not shown), for example. The output from such a light detector unit may reflect mechanical pressure or stress on membrane 20. For example, the output from the light detector unit may be affected by the thickness of the fluid 24 in the sensing device 16. The output may also be affected by, for example, the membrane's 20 elastic properties or changing shape, the viscosity of base 22, and the properties of reservoir 14, for example, if the expansion of the reservoir exerts forces. Calibration tests may be performed to determine the effects of the fluid type, membrane type and/or other suitable components on the in-vivo pressure or stress indication. A number of suitable mechanical or other effects may be used to affect the output from a light detector.

[0030] As can be seen with reference to **Fig. 2B**, when moderate force is exerted on membrane 20, the membrane may be stretched or deformed, forming, for example, an indented concave shape 34 and forcing fluid 24 from between faces 20, 22 into the fluid reservoirs 14a and 14b, via openings 26. According to one embodiment, fluid reservoirs 14a, 14b are expandable and may be configured to accommodate the expelled fluid.

[0031] Since the membrane 20 in the case described in Fig. 2B is indented, the length of the light passage through fluid 24 may be shortened and therefore the intensity of the reflected light, indicated by the thickness of beams 36, may be intensified when compared to the reflected light in the non-

pressured state illustrated in Fig. 2A. In some embodiments, coloring of fluid 24 may reduce the intensity of light passing through the fluid, and thus the smaller the thickness of the fluid, the larger the intensity of light emerging from the fluid. Other mechanical effects may cause pressure or tension on membrane 20 to affect the intensity, direction or other properties of light passing through device 10. The output of the light detector unit may increase, possibly proportionally in relation to the reflected light, thereby indicating the pressure being exerted on sensing device 16.

[0032] **Fig. 2C** schematically illustrates the effect of further increasing the pressure on membrane 20. In this case, membrane 20 may be stretched even more, forcing additional fluid 24 into fluid reservoirs 14A, 14B, via openings 26. In this case, the intensity of the reflected light beams 38 may be substantially greater than beams 32, and even greater than beams 36 (in Figs. 2A and 2B respectively), indicating greater pressure being exerted on sensing device 16.

[0033] As described with reference to Figs. 2B and 2C, the indentation of membrane 20 may shorten the length of the light passage in fluid 24 thereby intensifying the reflected light (indicated by the thickness of beams 36 and 38 respectively). The increased output of the photosensitive unit may indicate the pressure being exerted on the sensing device 16. The output of the photosensitive unit may be non-linear and may be strongly dependent on the membrane elastic properties. For example, the force and/or pressure may be determined from the photosensitive unit output by, for example, a processor or manually, by, for example, comparing the optic change with a calibration curve.

[0034] Reference is now made to **Fig. 3**, which schematically illustrates an exemplary prior art in-vivo imaging device 50, such as an ingestible capsule. Device 50 may include an imaging system for obtaining images from inside a body lumen. The imaging system may include at least one illumination source 54, such as, for example, a white LED; an imager, such as, for example, a CMOS imager 56, which may detect images; and an optical system 58, which may include for example, a lens, which may focus the images onto imager 56. Illumination source 54 may illuminate inner portions of a body lumen through

optical window 52. Device 50 may further include an optical window 52, a transmitter 60, such as an RF (radio frequency) transmitter, possibly incorporated on a Application Specific Integrated Circuit (ASIC), which may include control capability (control capability may be included in a separate device), and an antenna 62 for transmitting received image data from imager 56; and a power source 64, for providing power to the electrical elements of device 50. In one embodiment, power source 64 includes one or more batteries. Embodiments of ingestible imaging devices are described, for example, in US Patent No. 5,604,531 and in Publication Number WO 01/65995, both of which are assigned to the common assignee of the present application and incorporated herein by reference. Other configurations or sets of components may be used. For example, a CCD or other suitable imager may be used. Power sources other than batteries may be used.

[0035] Reference is now made to **Fig. 4**, which schematically illustrates a pressure or stress sensing sub-system 100 integrated into an in-vivo imaging device 102, such as, for example an ingestible capsule, constructed and operative in accordance with an embodiment of the present invention. Device 102 may be similar to the in-vivo imaging device 50 of Fig. 3, and common elements having similar functions have been denoted with the same numerical references and will not be described further. Device 102 may be similar to embodiments described in U.S. 5,604,531 and/or in Publication Number WO 01/65995, although other configurations may be used. While device 102 is in one embodiment a swallowable capsule, the device need not be swallowable and need not be a capsule.

[0036] In the embodiment illustrated in Fig. 4, device 102 may include at least one optical window 52, which may be formed within the shell 101 of device 102; at least one imaging system 104 for obtaining images from inside a body lumen; a transmitting system 106 for transmitting at least image data received from imaging system 104 (typically using radio waves, although other suitable methods may be used); and a power source 64, for providing power to the electrical elements of device 102. Imaging system 104 may include one or more illumination source(s) 54, such as, for example, a white LED; an imager 56, for example, a CMOS imager, which may detect the images; and an

optical system 58, which may, for example, focus images received onto imager 56. It will be appreciated that imager 56 may include other image sensors, such, for example, a CCD. Illumination source 54 may illuminate inner portions of body lumen through optical window 52. Transmitting system 106 may include a controller, for example as ASIC controller 60, associated with a transmitter, and an antenna 62. Device 102 may include a processing unit, optionally within ASIC controller 60, to process at least imaging data. Controllers or processors other than ASIC units may be used. Additionally or alternatively, an external processing unit may be provided, for example, in a data receiver unit borne by a user, or in a computer system used to process in-vivo imaging data etc.

[0037] Sensing sub-system 100 may include at least one light detector unit 105, which may be, for example, any suitable photosensitive mechanism such as, for example, a photocell, a photodetector, an imager, etc. In the embodiment of Fig. 4, light detector unit 105 may include, for example, a photocell (for example, an annular photocell, although other suitable photocells may be used) proximate to shell 101 of device 102. One or more detectors 105 may be positioned in any suitable location(s) to enable receipt of light reflected from a sensing sub-system membrane, e.g., membrane 122. ASIC controller 60 may be configured to receive and transmit the output of light detector unit 105 to an external receiving unit. Alternatively, light detector unit 105 may be configured to directly communicate with an external receiving unit. In an alternate embodiment, light detector units 105 may not be necessary; imager 56 may receive light from sensing sub-system 100 to provide an indication of stress or pressure on the device 102.

[0038] Sensing sub-system 100 may further include at least one sensing device 110 and at least one appended fluid reservoir 120 (for example, as detailed in Figs. 6A-C) which may be, for example, incorporated within or attached to shell 101 of device 102. For illustrative purposes, two sensing devices 110 are shown, on either side of optical window 52. Device 103 may have more than one window 52. Sensing device 110 may be positioned in the field of illumination of illumination source 54, or any other suitable illumination source, and in the field of view of light detector unit 105 or of

imager 56. For example, an illumination source separate from an illumination source used for imaging (e.g., 54) may be used. In other embodiments more than two sensing subsystems 100 and/or sensing devices 110 may be used. Sensing subsystems 100, sensing devices 110, illumination sources 54, and/or windows 52 may be positioned in any suitable locations within device 102. Sensing devices 110 may be similar to sensing devices depicted elsewhere herein, such as in Figs. 1-2 and 6-7.

[0039] Reference is now made to **Fig. 5**, which is a schematic illustration of an in-vivo device and processing system 500, according to some embodiments of the present invention. System 500 may include, for example: an in-vivo device 510, for example, a swallowable capsule, a data receiver unit 512 to receive at least in-vivo device data; a processing unit 514 to process at least in-vivo device data; and displaying unit, such as a monitor 516, to display at least in-vivo device data. For example, data receiver unit 512 may receive the data from in-vivo device 510, and may thereafter transfer the data to a data processing unit 514, and optionally a data storage unit 519. The data may be displayed on monitor 516. Data receiver unit 512 may be separate from processing unit 514 or combined with it. Data processing unit 514 may be, for example, a personal computer or workstation, and may include, for example, a processor memory etc. Data processing unit 514 may be configured for real time processing and/or for post processing to be viewed or otherwise displayed at a later date. Units 514, 516 and 519 may be integrated into a single unit, or any combinations of the various units may be implemented. Of course, other suitable components may be used. Device 510 may be an imaging device, but need not be an imaging device. Processing system 500 can be for example, similar to that described in US Patent No. 5,604,531 and in Publication Number WO 01/65995, both of which are assigned to the common assignee of the present application and incorporated herein by reference. Imager 56 or photo detector, for example, may transmit information via transmitter 60, and such information may be received by external receiver 512. Transmission and reception may be wireless or through a wired connection.

[0040] Reference is now made to **Figs. 6A-6C**, which are enlarged details of the construction and operation of sensing device 110, which may for example be integrated into device 102 (e.g., in Fig. 4). Sensing device 110 may include a substantially transparent base 112 integrally formed on the inner face of sensing device 110, and a membrane 114 integrally formed on the outer face of device 110. Sensing device 110 may include a material, such as a fluid 116, which may fill the space between the inner and outer faces of the sensing device 110. At least one channel 118 may be formed within sensing device 110, for example, enabling communication between fluid 116 in sensing device 110 and fluid reservoir 120. The above-described communication may occur, for example, within the shell of device 102. Fluid 116 may be, for example, transparent, white, colored, etc. It will be appreciated by persons skilled in the art that though fluid reservoir 120 is shown as a single entity, it may comprise two or more separate reservoirs in communication with fluid 116.

[0041] According to an embodiment of the present invention, a substantially rigid and reflective base 122 may be positioned within sensing device 110. For example, reflective base 122 may have a triangular wedge-shaped cross-section, as shown in **Fig. 6A**. It will be appreciated by persons skilled in the art that reflective base 122 may conform to any suitable shape. Furthermore, reflective base 122 may be rigid or non-rigid. As can be seen in Fig. 6A, incident light beams 124 from an illumination source (e.g., from illumination source 54) may pass through transparent base 112 (Fig. 5A) and through fluid 116 to reach reflective base 122, where the light may be reflected as indicated by beams 126 onto a light detector (e.g., unit 105 or imager 56).

[0042] **Fig. 6B**, to which reference is now made, illustrates the action of pressure on the outer face of device 102, for example, when device 102 is pushed against the gastro-intestinal tract wall, and/or when a contraction or movement of the wall causes the wall to press against sensing device 110. When force is exerted on membrane 114, membrane 114 may be stretched or bent, forming, for example, an indented concave shape and forcing fluid 116 into fluid reservoir 120, for example, via channel 118. Other suitable shapes may be formed from pressure or stress. Fluid reservoir 120 may be

configured to accommodate any expelled fluid. Wedge-shaped reflective base 122 may be attached to membrane 114, optionally at the center of membrane 114, to maintain an appropriate spatial orientation with reference to membrane 114, even when membrane 114 is indented.

[0043] In the case where membrane 114 is indented, the length of the light passage in fluid 114 may be shortened and therefore the intensity of the reflected light, indicated by the thickness of the beams 130, may be intensified, in comparison with the light reflected in a non-pressured state (e.g., Fig. 6A). The output of a photosensitive system (e.g., unit 105) may increase proportionally to the intensity of the reflected light, thereby indicating the pressure being exerted on sensing device 110.

[0044] In an alternative embodiment of the present invention, as illustrated in **Fig. 6C**, sensing device 110 may further include a reflective device such as an adjustable mirror 140, optionally in place of reflective base 122 of Figs. 6A and 6B, angled with reference to transparent base 112. Mirror 140 may be configured to reflect the incident light beams 142 from an illumination source through transparent base112 (beams 144) and fluid 116. Beams 144 may reach membrane 114 and may be reflected, as depicted by beams 146, onto a light detector.

[0045] The angle of mirror 140 with respect to membrane 114 may be adjusted so that the light reaches, for example, the center of membrane 114. In such an example light rays 144 may be reflected at the same angle (as shown in Fig. 6B) onto a light detector such as detector 105. The central part of membrane 114, for example, may be made rigid, relative to the elasticity of membrane 114, to ensure that light will reach the light detector.

[0046] Reference is now made to **Figs. 7A and 7B**, which schematically illustrate a sensing module, generally designated 200, constructed and operative with reference to a further embodiment of the present invention. Sensing module 200, which may be incorporated within an in-vivo imaging device shell, or otherwise attached to or included within a device (for example, an ingestible capsule, an endoscope, a needle, a catheter, etc,), optionally in line of sight of an imaging device such as imager 56. Sensing

module 200 may include a pressure sensitive chamber 202. Chamber 202 may be transparent on inner face 204 of the device shell (e.g., the side facing a light source and an imager) and may have an opaque background on external face 206.

[0047] Chamber 202 may be filled, for example, with a multitude of particles 208. Particles 208 may be transparent, translucent, white, or have any combination of colors or properties, possibly depending on the color of external face 206 of the device shell. If external face 206 is white, for example, chamber 202 may be filled with colored particles, and if external face 206 is colored, for example, chamber 202 may be filled with white particles etc. When there is no stress on chamber 202, for example as is depicted in Fig. 7A, imager 56 may detect particles 208 but not external face 206 (e.g., the background), since face 206 may be covered by, for example, light absorbent particles 208. If there is stress on the device shell, for example as is depicted in Fig. 7B, by arrows 210, particles 208 may be pushed away from the point of pressure, on either side of the pressure point, thereby revealing external face 206 of the device shell. The change in the color of the light reflected back to an imager may indicate whether particles 208 or external face 206 reflected the light, thereby indicating, for example, whether pressure or stress are acting on in-vivo device 102.

[0048] In another embodiment of the present invention reflected light may be incident on imager 56, possibly on a dedicated portion of imager 56, the characteristics of the reflected light being presented as an image. For example, in one embodiment the image recorded by imager 56 may indicate a movement, e.g., an expansion, of at least a spot of reflected light, which may indicate a change in the configuration of a pressure or stress-sensing module, and thus a change in pressure or stress on the overall device 102. For example, in another embodiment a portion, for example, an unused section of pixels of the image recorded by imager 56 may indicate a change in the configuration of a pressure or stress-sensing module, and thus a change in pressure or stress on the overall device 102.

[0049] Reference is now made to **Fig. 8**, which is a flow chart depicting a method for measuring in-vivo pressure or stress, according to some

embodiments of the present invention. The method, which may be, for example, implemented using a pressure sensing device associated with an in-vivo imaging device, may include, at block 800, radiating a light beam through a substantially transparent base and a fluid of an in-vivo pressure sensing device. At block 805 the beam may be reflected, for example by a substantially reflective membrane, to a light detector. For example, a photodetector, an imager, etc., may receive light rays. At block 810 the in-vivo pressure or stress on the membrane may be measured, based on, for example, the light intensity of the light reaching the light detector, as is described in detail above. The measurement of the in-vivo pressure on the membrane may be computed by a processor. In some embodiments a substantially reflective base may be used to channel incoming light to at least one light detector. In some embodiments a mirror may be used to channel incoming light to the substantially reflective membrane. In some embodiments the fluid through which the light travels may have substantially reflective particles, which may be used to reflect incoming light to at least one light detector.

[0050] In some embodiments, a device and method may be used to measure localized stress or pressure in a lumen, as opposed to generalized pressure within a lumen. For example, the stress or pressure of a contraction of a lumen wall in a particular location may be measured. In other embodiments, other measurements, such as generalized pressure, may be recorded.

[0051] It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims, which follow:

CLAIMS

1. An in-vivo sensing device; comprising:

-a substantially transparent base;

a pressure-sensitive membrane; and

a fluid disposed between said transparent base and said membrane.

2. The device of claim 1, comprising at least one fluid reservoir being associated with at least one opening in said transparent base.

3. The device of claim 2, wherein said reservoir is adapted to expand to receive fluid expelled from the area between said transparent base and said membrane.

4. The device of claim 1, comprising an illumination source.

5. The device of claim 1, comprising an imaging system.

6. The device of claim 5, wherein said imaging system comprises:

an imager and

an optical system to focus images onto said imager.

7. The device of claim 1, wherein said membrane is substantially reflective.

8. The device of claim 1, comprising a light detector.

9. The device of claim 1, comprising a substantially reflective base configured to channel the reflection of incident light.

10. The device of claim 1, comprising a mirror.

11. The device of claim 1, wherein said fluid includes substantially reflective particles.

12. The device of claim 1, comprising a transmitter.

13. The device of claim 1, wherein the device is autonomous.

14. The device of claim 1, wherein said transparent base is substantially rigid.

15. An in-vivo device, comprising:

an imaging system; and

an in-vivo sensing device to sense in-vivo stress.

16. The device of claim 15, comprising an illumination source.

17. The device of claim 15, comprising a transmitter.

18. The device of claim 15, comprising a processing unit.

19. The device of claim 15, wherein said sensing device further comprises:

a substantially transparent base;

a flexible membrane; and

a fluid disposed between said transparent base and said membrane.

20. The device of claim 19, wherein said sensing device further comprises a fluid reservoir being associated with said fluid disposed between said transparent base and said membrane.

21. The device of claim 19, wherein said sensing device further comprises a fluid reservoir being associated with an opening in said transparent base.

22. The device of claim 19, wherein said sensing device further comprises a substantially reflective base.

23. The device of claim 19, wherein said sensing device further comprises a mirror.

24. The device of claim 19, wherein said sensing device further comprises a light detector.

25. The device of claim 19, wherein said fluid comprises colored particles.

26. A method for measuring in vivo pressure comprising:

illuminating an in-vivo pressure sensing device;

recording light remitted from said sensing device; and

indicating in-vivo pressure on said sensing device.

27. The method of claim 26, comprising computing said in-vivo pressure using a processor.

28. The method of claim 26, comprising reflecting said illumination using a substantially reflective membrane to at least one light detector.

29. The method of claim 28, comprising reflecting said illumination to a pressure sensitive membrane in said pressure sensing device.

30. The method of claim 26, comprising reflecting said illumination using a substantially reflective base in said pressure sensing device..

31. The method of claim 26, comprising reflecting said illumination using substantially reflective particles within said pressure sensing device.

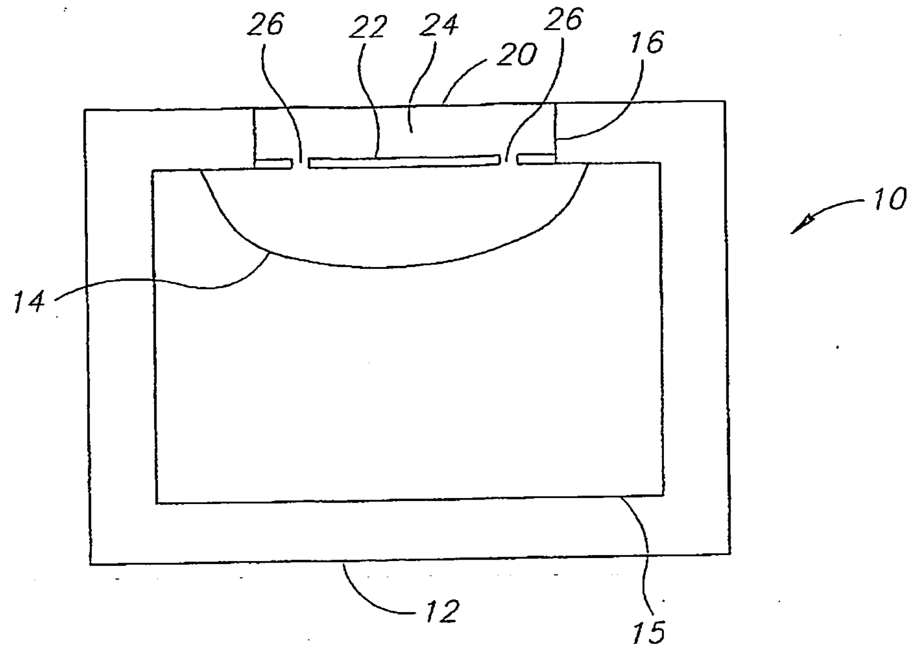


FIG.1

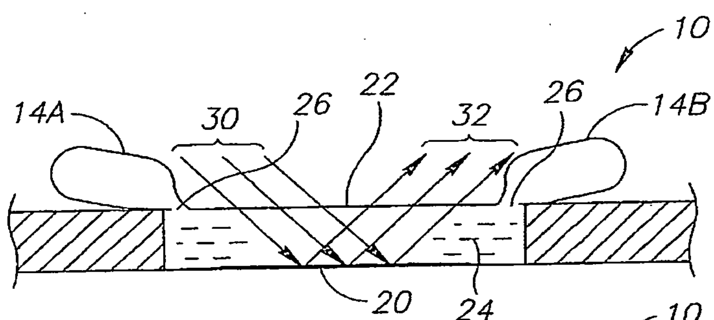


FIG.2A

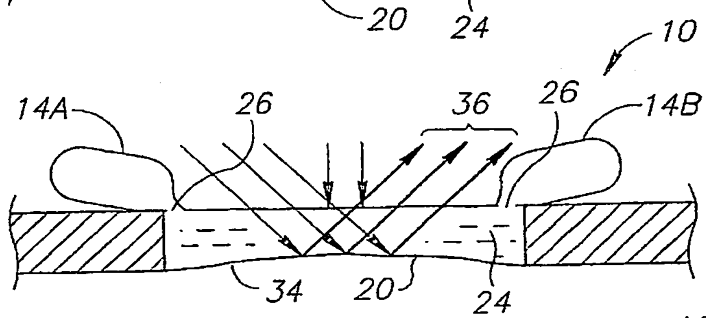


FIG.2B

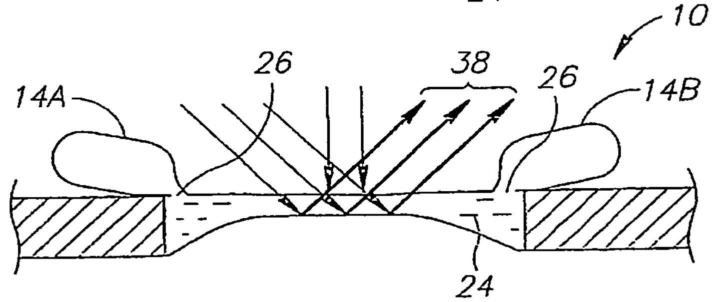


FIG.2C

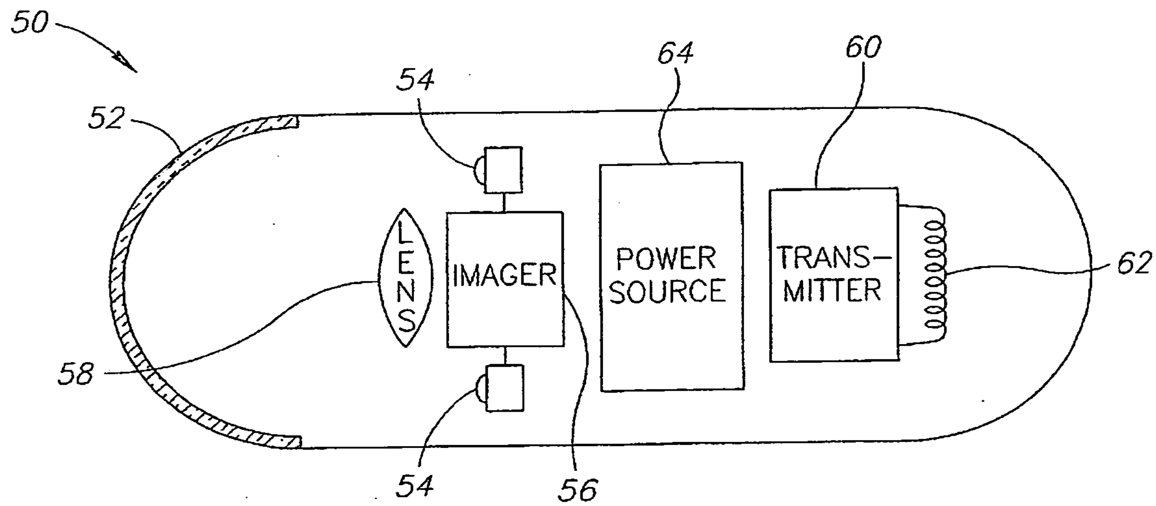

50
52
54
64
60
LENS
IMAGER
POWER SOURCE
TRANS-MITTER
62
58
54
56

FIG.3

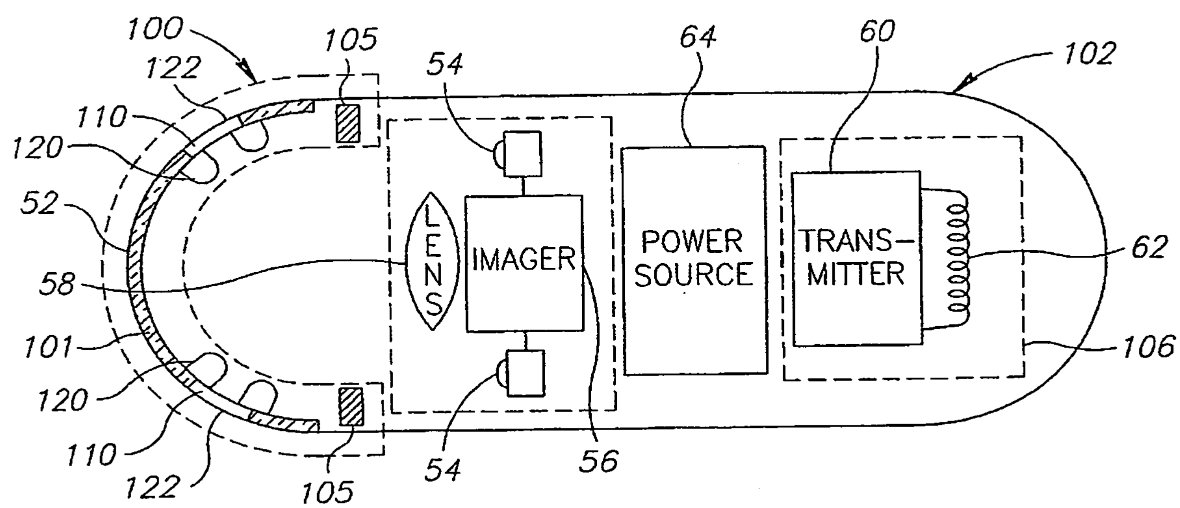

100
105
122
54
64
60
102
110
120
52
LENS
IMAGER
POWER SOURCE
TRANS-MITTER
62
58
101
106
120
110
122
105
54
56

FIG.4

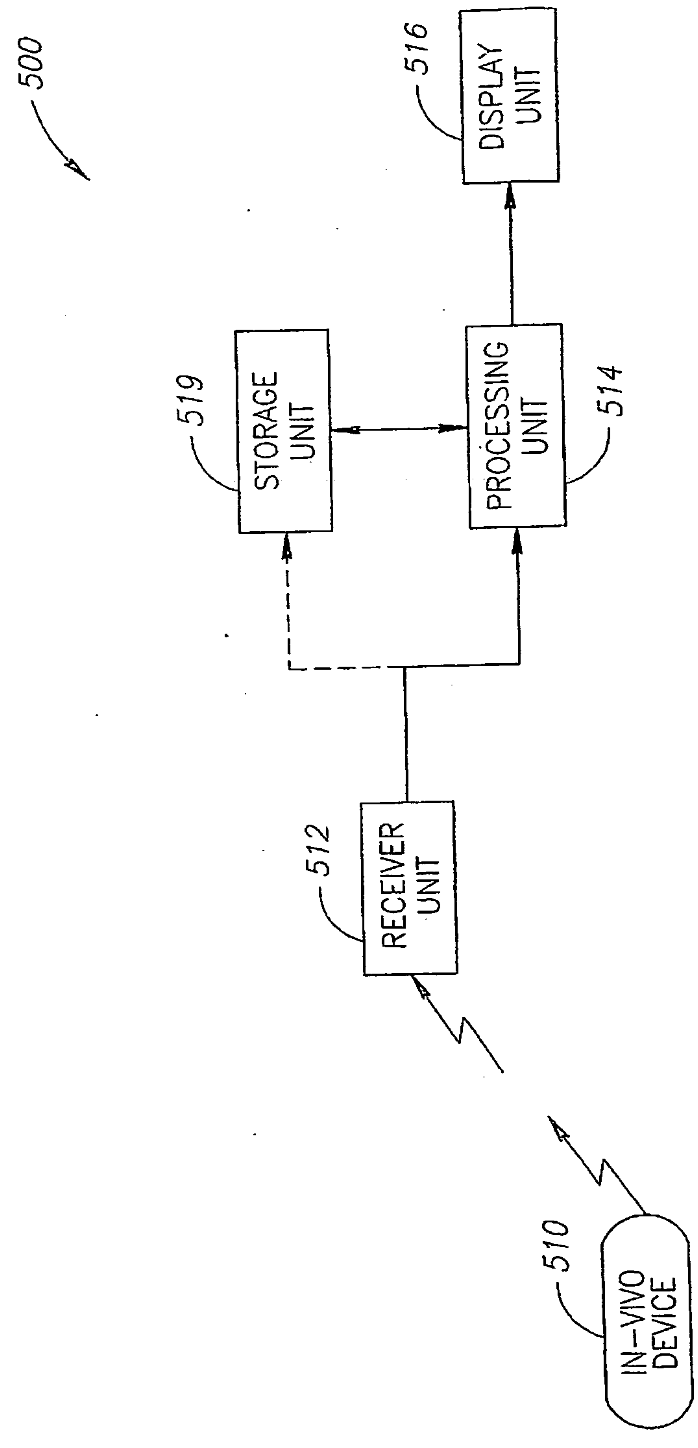

500
516
DISPLAY UNIT
519
STORAGE UNIT
PROCESSING UNIT
514
512
RECEIVER UNIT
510
IN-VIVO DEVICE

FIG.5

FIG.6A

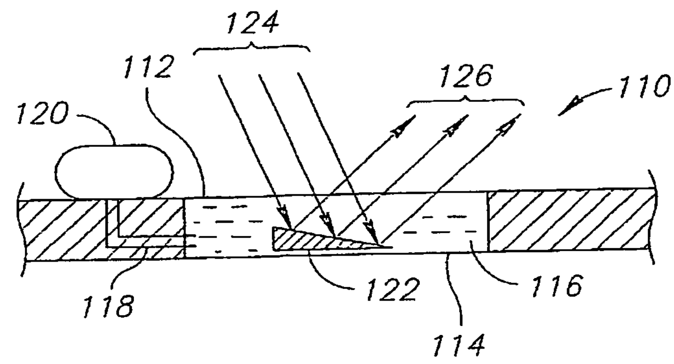


FIG.6B

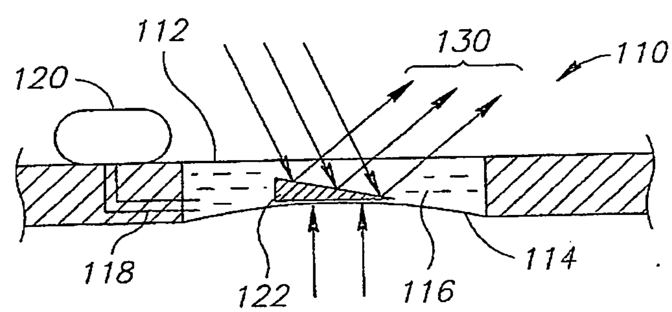
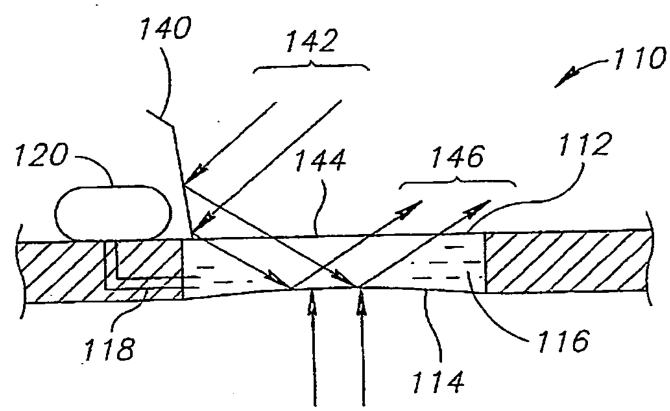


FIG.6C



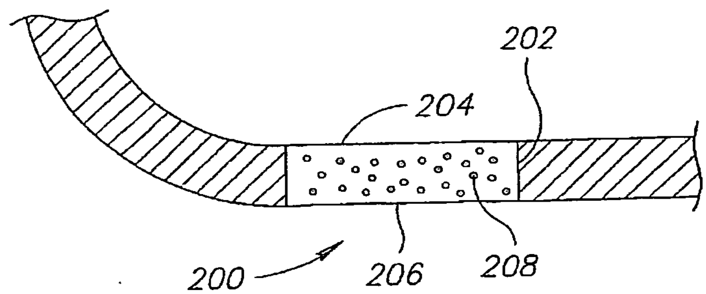


FIG.7A

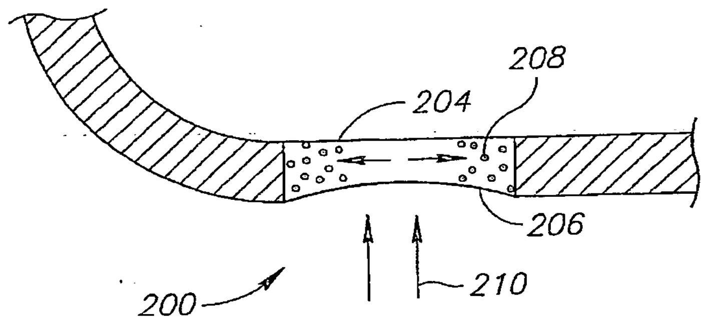


FIG.7B

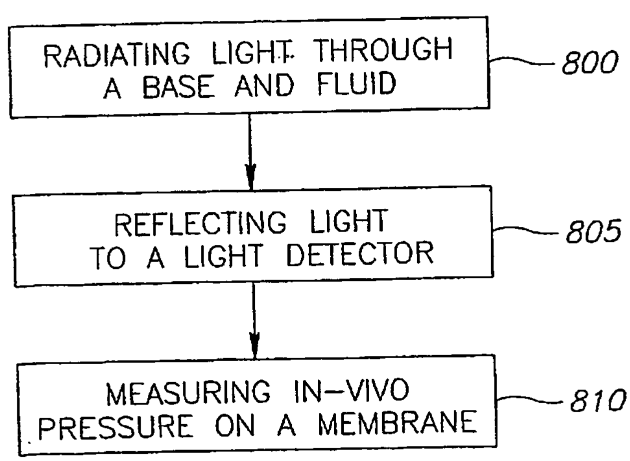


FIG.8